Temperaments.[illegible]

Tunings of the scale in which some or all of the concords are made slightly impure in order that few or none will be left distastefully so. Equal temperament, in which the octave is divided into 12 uniform semitones, is the standard Western temperament today except among specialists in early music. This article traces the history of temperaments in performing practice and in relation to the main lines of development in the history of harmony; for additional technical and historical details see Tuning, Pythagorean intonation, Just intonation, Microtone, Mean-tone, Well-tempered clavier, Equal temperament and Interval, especially Table 1.

[illegible] 12 [illegible] Tuning, Pythagorean intonation, Just intonation, Microtone, Mean-tone, Well-tempered clavier, Equal temperament and Interval, [illegible] Table 1[illegible]

1. Introduction.

2. Quasi-Pythagorean temperament.

3. Regular mean-tone temperaments to 1600.

4. Irregular keyboard temperaments to 1680.

5. Equal temperament to 1735.

6. Regular mean-tone temperaments from 1600.

7. Irregular temperaments from 1680.

8. Equal temperament from 1735.

9. Fretted instruments.

10. Difficulties in interpreting theoretical writings.

11. Temperament and harmony.

1. Introduction.

Since the 15th century, tempered tuning has characterized keyboard music

and in Western culture the art music of fretted instruments such as the lute. Its prevalence is due mainly to the fact that the concords of triadic music – octaves, 5ths and 3rds – are in many cases incommensurate in their pure forms. Three pure major 3rds (e.g. Ab–C–E–G#) fall short of a pure octave by approximately one fifth of a whole tone (lesser diesis); four pure minor 3rds (G#–B–D–F–Ab) exceed an octave by half as much again (greater diesis); the circle of twelve 5ths, if the 5ths are pure, does not quite cumulate in a perfect unison; and, most important of all in the context of Renaissance and Baroque music, the whole tone produced by subtracting a pure minor 3rd from a pure 4th (C–F–D) is about 11% smaller than the whole tone produced by subtracting a pure 4th from a pure 5th (C–G–D). These discrepancies are summarized in Table 1.

1[illegible]

15 [illegible] [illegible]Ab-C-E-G#[illegible] 1/5 [illegible]“[illegible] diesis”[illegible]lesser diesis[illegible]G#-B-D-F-Ab[illegible] 1/10 [illegible]“[illegible] diesis”[illegible]greater diesis[illegible]“[illegible]”[illegible]C-F-D[illegible]C-G-D[illegible] 11%[illegible]

Not all timbres, however, are equally conducive to temperament. In general, it is only when the component overtones of the timbre (together with the fundamental tone of the note) form a virtually pure harmonic series that consonant intervals will sound sufficiently different in quality from dissonant ones for the need for tempering the concords to arise. A pronounced degree of inharmonicity in the timbre, as in a set of chimes or a xylophone, eliminates the qualitative difference, except in the case of a unison or octave, between the sound of a pure concord and that of a slightly impure or tempered one. (An artful exception to this general rule is mentioned in the last paragraph of §6 below.)

[illegible]

Moreover, theorists are obliged to contrive specific mathematical schemes for tempering the scale only when the medium of performance allows little or no flexibility of intonation, for only then does the incommensurability of pure concords have to be dealt with systematically by the tuner rather than ad hoc by the performer. A singer or violinist will inflect certain intervals depending on their immediate context; but this does not produce thereby a specific temperament because at different moments the performer will represent each note of the scale by different shades of pitch within a fairly narrow band

(about half as wide again, perhaps, as the vibrato). On most keyboard instruments and the harp, however, the complete lack of such flexibility obliges the tuner to impose a specific temperament, while on fretted instruments, the clavichord, and many wind instruments, the tuner or maker establishes a certain model of intonation, albeit one that an ingenious player can modify significantly during performance.

□□

For present purposes four main types of temperaments may be distinguished: equal temperament, mean-tone temperament, irregular temperaments and quasi-Pythagorean temperament. This article will describe primarily the history of their use, but some plain and easy arithmetic is necessary here to distinguish one from another.

□□□□□□□□□□□□□□□□□□□□“□□□□□”□mean-tone temperament□□“□□□□”□irregular temperaments□□□“□□□□□□□”□quasi-Pythagorean temperament□□□

For a series of twelve 5ths or 4ths to produce cumulatively a perfect unison and so comprise the ‘circle of 5ths’, each must be tempered by an average of 1/12 of the Pythagorean comma (hence about two cents) – 4ths larger than pure, 5ths smaller. If three major 3rds are to reach a full octave they must average about 14 cents (1/3 of the lesser diesis) larger than pure, while four minor 3rds, in order not to exceed a pure octave, must average about 16 cents (1/4 of the greater diesis) smaller than pure. In equal temperament, which is modelled on these averages, the major 3rds are thus tempered seven times as much as the 5ths, and the minor 3rds and major 6ths eight times as much. Historically this is nearly as important an aspect of equal temperament as the well-known fact that it divides the octave into 12 equal semitones. As a harmonic interval the major 3rd f–a at modern concert pitch, for instance, beats seven times per second – too fast for the ear to trace, even subliminally, the rise and fall of each beat, and fast enough to cause an intermittence of tone that is likely to strike an unaccustomed ear as unpleasant in many contexts.

□□□□□□□□□□□□□□□□□□□□□□□□□□□□“□□□□”□□□□□□□□□□□□□□□□□“□□□□□□□”□□□□□□□□□□□□□□□□□□2 □□□——□□□14 □□□□□□ diesis □□□□□□□□□□□□□□□□□□□□□□□□□□□16 □□□□□□ diesis □□□□□□□□□□□□□

[illegible]“[illegible]”[illegible] f-a[illegible]——[illegible]

To avoid such heavily tempered 3rds and 6ths, Renaissance and Baroque keyboard musicians tempered their 5ths two or even three times as much as in equal temperament. This choice entailed ‘breaking’ the circle of 5ths, a fact reflected in traditional pitch notation and nomenclature with their enharmonic distinctions between flats and sharps. If all the good 5ths in such a tuning are diminished the same amount, the result may be called a regular mean-tone temperament, although some writers restrict the term ‘mean-tone’ to that scheme in which 5ths are tempered so as to produce exactly pure major 3rds. In any mean-tone temperament the diatonic semitones are larger than the chromatic (for instance, D# is lower in pitch than Eb).

[illegible]“[illegible]”[illegible]“[illegible]”[illegible]mean-tone temperament[illegible]“[illegible]”[illegible]mean-tone[illegible]“[illegible]”[illegible]mean-tone temperament[illegible] D#[illegible] Eb[illegible]

Certain irregular keyboard temperaments, in which different 5ths are tuned differently but none rendered unserviceable, were favoured during the late 17th century and the 18th because they enabled the more frequently used 3rds to be tempered less than those used infrequently, and because the various keys thereby gained a diversity of intonational shading that was highly valued by connoisseurs and formed a prominent aspect of 18th-century musical thought. In 17th-century France an irregular scheme midway between a regular mean-tone and a typical 18th-century irregular temperament seems to have played a role in the contemporaneous development of the French keyboard style. Yet another, very different kind of temperament – ‘quasi-Pythagorean’ – can be derived from the fact that the sum of two major 3rds each of which is larger than pure by a syntonic comma (for example, Ab–C–E when the 5th and 4ths Ab–Eb–Bb–F–C–G–D–A–E are all pure) falls short of an octave by almost a pure major 3rd (in this case E–G#).

[illegible] 17 [illegible] 18 [illegible]——[illegible]——[illegible] 18 [illegible] 17 [illegible]“[illegible]”[illegible]mean-tone temperament[illegible] 18 [illegible]——“[illegible]”[illegible]quasi-Pythagorean[illegible]——[illegible] syntonic comma [illegible] Ab-C-E[illegible] Ab-Eb-Bb-F-C-G-D-A-E [illegible] E-G#[illegible]

The word ‘temper’ and its derivatives were originally applied to music in a broader context than they now denote. Carter’s Dictionary of Middle English Musical Terms (1961) indicates that the adjective ‘temperate’ was once used in a general sense to mean ‘musically controlled’, as in a reference (1398) by John of Trevisa to a ‘swete voys an temperate sowne’. But the verb ‘temperen’ and its past participle ‘tempered’ referred in Middle English unequivocally to tuning, albeit pure tuning as well as tempered tuning in the modern sense; and this meaning was still encountered in 1593: ‘Whereupon M. Barleycap tempered up his fiddle, and began’ (‘Temper’, OED). In the writings of Zarlino, the eminent 16th-century Italian theorist and musician, ‘temperamento’ was closely associated with the term ‘participatio’ by which, according to Gaffurius in 1496, Renaissance organists referred to their use of 5ths diminished ‘by a very small and hidden and somewhat uncertain quantity’.

Temperaments

2. Quasi-Pythagorean temperament.

Late 14th- and early 15th-century keyboard instruments that were fully chromatic, that is, with 12 notes in the octave, were normally tuned with 11 pure 5ths among the naturals and hence automatically with one sour 5th, a comma smaller than pure, which was, by most accounts between B and F (the evidence for this comes mainly from Italy and southern France: Dijon, Liège, Padua, Mantua, Parma, Ferrara, Milan, Florence, Urbino). Such a tuning happens to yield virtually pure 3rds between the naturals and sharps (D–F–A–C–E–G–B–D) and much less nearly pure 3rds, a comma larger or smaller than pure, among the naturals (D–F–A–C–E–G–B–D) and between the naturals and flats (D–F–A–C–E–G–B–D). The apparent consequences in some extant early to mid-15th-century keyboard music are discussed in Pythagorean intonation. The kind of triadic harmony which was involved – wherein, among the major triads, those on D, A and E are treated as distinctly more euphonious and stable than those on B, F, C and G – can be found also in non-keyboard compositions by Matteo da Perugia, Andrea dei Servi and, in his earliest songs, Guillaume Du Fay (Lindley and Boone).

Singers can hardly be expected to have maintained the distinction between pure and impure triads; if they could manage a fairly pure triad at one place in the music, they would most likely be unwilling to produce on purpose a distinctly impure one somewhere else. However, the notion that a chain of ‘perfect’ concords (5ths, 4ths) yields ‘imperfect’ ones (3rds, 6ths) which are so euphonious that they serve as stable sonorities in the harmony, as in ex.1 and ex.2, is a hallmark of temperament. And the fact that even in these vocal works, only triads containing a sharp were treated as stable (see ex.19 and the discussion in §11) suggests that some kind of keyboard instrument, perhaps the clavichord if not the organ, was used as a help in composing

them. The theoretical amounts of tempering – less than 1/4 of a cent for each 5th – are so small that no-one at the time noticed; and indeed Helmholtz in the 19th century tempered in this way the intervals on his ‘justly intoned harmonium’ with 24 different pitches in each octave (see Just intonation, §2).

Temperaments

3. Regular mean-tone temperaments to 1600.

In the last chapter of his Musica practica (Bologna, 1482) Bartolomeo Ramis de Pareia indicated that mean-tone temperament was in common use on keyboard instruments of his day. Earlier in the book he had presented a new, mathematically simple scheme which he said even young singers could use for a monochord to provide a model scale for plainchant. In that scheme the wolf 5th was ostensibly between G and D. But his elaborate and comprehensive rules, in the last chapter, for avoiding ‘bad’ intervals on fully chromatic instruments (‘instrumenta perfecta’) leave no doubt that in general practice G–D was perfectly serviceable and the wolf 5th was between C and A. This is corroborated by his lists of ‘good’ and ‘bad’ semitones, whole tones, and major and minor 3rds, and by the pattern of his nomenclature for the sharps and flats. Ramis expressed particular concern that only ‘good’ major 6ths and 3rds be used in cadential progressions. There is confirmation that ‘good’ did not mean ‘Pythagorean’ in a letter (published in 1518) from his disciple Giovanni Spataro to Franchinus Gaffurius. Criticizing Gaffurius for saying that the syntonic comma was an insignificant intervallic quantity, Spataro argued, on behalf of Ramis, that for practical music the harsh Pythagorean monochord had to be reduced and smoothed for the ear (‘el duro monochordo pythagorico … riducto in molle al senso de lo audito’). Gaffurius, although a strict Pythagorean in his mathematical calculations of intervals, acknowledged in 1496 that organists tempered their 5ths, while his chromatic monochord of 1518 (reprinted in 1520) indicates that G and D differed from A and E. Ramis’s discussion of ‘good’ cadential 6ths and 3rds mentions the device, which later became widespread in Italy on keyboard instruments designed for mean-tone temperament (see Barnes, 1971, and Dupont, 1935), of doubling the accidentals A and E to provide their enharmonic neighbours G and D; and the 1480 contract for the cathedral organ at Lucca appears to refer to such a device. The use of regular mean-tone temperaments had probably evolved from ad hoc alterations of certain earlier 15th-century untempered schemes in which, as in Ramis’s own pedagogical monochord, the wolf 5th was placed ostensibly among the naturals (Lindley, 1975–6). Perhaps the oldest known keyboard composer whose music requires a mean-tone temperament for its proper effect was Conrad Paumann. His use of triads, as in ex.3, suggests that he regarded them as solid vertical sonorities, more so than they would in fact be in Pythagorean intonation. The use of triads in contemporary vocal music (e.g. Ockeghem, Busnoys and late Du Fay)

is similar in this respect.

No particular shade of mean-tone temperament on keyboard instruments – such as 2/7-comma, 1/4-comma or 1/5-comma (see Mean-tone) – was favoured exclusively at any time during the Renaissance. The earliest mathematically specific formula was Zarlino’s scheme of 1558 for 2/7-comma mean-tone, in which major 3rds are very slightly smaller than pure. But Lanfranco’s keyboard tuning instructions of 1533 are unequivocally for some form of mean-tone, such as 1/5-comma or 1/6-comma, with major 3rds slightly larger than pure (and with the wolf 5th lying between G and E instead of between C and A as Ramis suggests). The same can be inferred from other writers, and not just those who cited Lanfranco. Schlick had implied in 1511 that some organists would prefer such a tuning to his own irregular scheme (see §4 below). The clavichord tuning instructions published by Tomás de Santa María in 1565, although clearly for some form of mean-tone, do not specify the exact quality of the major 3rds; but when Pietro Cerone copied these instructions in 1613 he added a few words to specify major 3rds slightly larger than pure and declared that this was the method most used by master organ builders (‘es manera mas usada de los Maestros de hazer Organos’). An approximation of 2/9-comma mean-tone (with major 3rds very slightly larger than pure) was described in 1590 by Cyriacus Schneegass, who may have confused it with 1/4-comma mean-tone.

Meanwhile Zarlino in 1571 described 1/4-comma mean-tone, which has pure major 3rds, in mathematically clear terms. He said it was new (‘un novo Temperamento & … una nova Participatione’); but Francisco de Salinas implied in 1577 that he had been using it in the 1530s. Many scholars attribute 1/4-comma mean-tone to Pietro Aaron in his harpsichord tuning instructions of 1523, but an equally legitimate interpretation of Aaron’s text suggests that while he would not have faulted regular 1/4-comma mean-tone, neither did he specify it. Salinas’s 1/3-comma mean-tone (1577), with its pure minor 3rds at the expense of major 3rds distinctly smaller than pure, does not seem to have been used much, even though it is very easy to tune. Zarlino described it in 1571 as less sonorous than 1/4- or 2/7-comma mean-tone, and added in 1588 that ‘it seems to me a bit more languid’ (‘anzi al mio parere è un poco più languido’). Its intervals are virtually identical, however, with those produced by an equal division of the octave into 19 parts, and in that guise it may have been familiar to Guillaume Costeley (Levy, 1955), as well as to Salinas himself and, later, Jehan Titelouze.

Evidently, then, all the forms of mean-tone temperament for which the essential mathematics were worked out by an anonymous early 17th-century Dutch colleague or disciple of Simon-Stevin (Lindley, 1984) – namely 1/3-, 2/7-, 1/4- and 1/5-comma mean-tone – had been in use, although 1/3-comma

probably least and 2/7-comma, which is difficult to tune precisely, perhaps less than 1/4-comma or some shade of mean-tone with major 3rds slightly larger than pure. No doubt most tuners, rather than trying to exemplify any particular mathematical model, merely sought to achieve sonorous 3rds and 6ths without making any 5th or 4th (other than the wolf) beat obstreperously. The instructions of G.B. Benedetti (1585), E.N. Ammerbach (1571) and G.P. Cima (1606), as well as those of Aaron and Santa María, reflect a certain freedom in this respect. Yet some of the best tuners may have sought a fairly precise regularity in the tempering of their intervals, if only for the sake of craftsmanship.

Musical evidence cannot show that any specific shade of regular mean-tone was exclusively favoured by any composer, but certain compositions benefit particularly from certain shades. The sprightliness of the sharps and B in ex.4, the first strain of an alman by John Bull, is better served by 1/5-comma than by 1/4- or 2/7-comma mean-tone. Ex.5, the opening of a toccata by Giovanni Gabrieli, gains a certain warmth and dignity in 2/7-comma mean-tone, while the relatively untuneful style of the entire toccata minimizes the dull melodic effect of the rather large diatonic semitones of 2/7- or 1/4-comma mean-tone. In 1/4-comma mean-tone the contrast between pure major 3rds and tempered minor 3rds prevents that effect of banality which in equal temperament would afflict the middle bars of ex.6, the opening of an organ verso by Antonio Valente; and in a more elaborate way the same kind of contrast – but involving tempered 5ths as well – is a positive delight when ex.7, the opening of a Cabezón tiento, is played in 1/4-comma mean-tone.

The possible use of regular mean-tone on 16th-century fretted instruments is discussed in §9 below.

Temperaments

4. Irregular keyboard temperaments to 1680.

Perhaps the earliest suggestion of an irregular keyboard temperament is an anonymous English prescription for organ pipes of about 1373 (‘Incipit mensura’, transcribed by K.-J. Sachs, 1970) instructing the builder that the correct pipe length for a chromatic note will halve the difference between its diatonic neighbours that form a Pythagorean whole tone (‘Ubicumque vis habere semitonium, semper fistulam inferiorem et superiorem in duas divides’). In the wake of the Renaissance revival of Euclidian geometry, Henricus Grammateus published in his arithmetic book of 1518 a simple diagram (fig.1) showing how the geometrical mean between two pipe lengths in the ratio 9:8 could be determined by drawing a semicircle on the sum of the lengths 9 and 8 taken as diameter, and then measuring the perpendicular from the juncture of the two lengths. By this means the Pythagorean whole

tone would be, in theory, divided into two musically equal semitones. Grammateus referred to these as ‘minor semitones’, and other theorists later used that term to designate equal semitones on the lute (see §9 below); but the context of the prescription leaves no doubt that he intended his ‘amusing reckoning’ (‘kurtzweyllig rechnung’) to be applied to organ pipes. Such a temperament would make both B–F and B–F sour, however, and even Barbour (1951), although ideologically attracted to it, described it as an organ tuning which ‘may have been used in practice but hardly by anyone who was accustomed, like Schlick, to tune by ear’. Nor does any extant Renaissance organ music avoid B–F as well as B–F.

The irregularities of a number of other schemes similarly deserve scant attention from the student of keyboard performing practice because they are only trivially different from regular schemes (e.g. Aaron, 1523), or quite incompetent (Reinhard, 1604) or of such limited historical and geographical scope (Douwes, 1699) as to be no more important for the history of musical style than the survival, to this day, of Pythagorean intonation as a provincial keyboard tuning method. Also relatively inconsequential, insofar as normal keyboard instruments are concerned, were expert and elaborate irregular schemes for the arcicembalo such as those of Vicentino (1555) and Trasuntino (instrument of 1606). However, irregular temperaments of musical consequence were published by Arnolt Schlick (1511) and Marin Mersenne (1635–6 and 1636–7).

Schlick’s temperament was an artful variant of regular mean-tone with major 3rds slightly larger than pure. The ten 5ths forming a chain from E to C were tempered more or less alike yet not all quite the same, for the major 3rds among the naturals were to be tempered less than those involving an accidental. Implicitly, B–D was not obliged to be serviceable at all, nor was the 5th from C to G or A. But to gain a G that could be used (if camouflaged by ornamentation or treated warily as in ex.8) to cadence on A, Schlick advised tempering the 5th A–E larger than pure. The result was to render E–G more or less Pythagorean and A–C (as in ex.9) more or less as in equal temperament (Husmann, 1967, and Lindley, 1974). Schlick remarked that some patrons would prefer to have an unequivocally serviceable G and no A at all, but he considered that arrangement an impoverishment of the harmonic resources of the organ; and he disapproved also of splitting accidentals to gain both enharmonic forms in a euphonious intonation. It is not known how widespread the use of Schlick’s tuning ever became, but his intended readership encompassed the Holy Roman Empire under Maximilian I.

The context of Mersenne’s step-by-step tuning procedure of 1635–6, and his subsequent acknowledgments of errors in the organ instructions, indicate that he had intended merely to prescribe regular 1/4-comma mean-tone (for the

organ on pp.364–5 and for the spinet on pp.108–9) where an ambiguity would allow an equivalent error to be inferred by a hasty reader. This error, concerning the 5ths down from F to B and thence to E, was evidently due to the fact that Mersenne had not tuned a keyboard instrument himself but was transmitting instructions from someone else (perhaps Jean Denis): hence he did not adequately clarify the fact that when one tempers an ascending 5th, for instance by tuning a G to a C, one makes the note G lower than pure in order to make the interval in C–G smaller than pure, but when one is tempering B to F one must tune the note B higher than pure in order to produce the same kind of interval, namely a 5th tempered smaller than pure. Virtually every set of step-by-step instructions for mean-tone temperament includes an awkward sentence or two about this point (Praetorius devoted nearly half a page to it). In Mersenne’s treatise the awkwardness was aggravated into succinct confusion. At one point he did specify that ‘il faut tenir la note de dessouz [B or E] un peu forte’; but elsewhere he gave a contrary impression, and in the instructions for tuning the spinet he said ambiguously: ‘Cette quinte doit estre augmentée au lieu que les précédentes ont esté diminuées’. The likelihood that some 17th-century readers – particularly musicians using the instructions without reading all the accompanying theory – interpreted this passage as a prescription for irregular temperament is shown by Chaumont’s ‘Méthode d’accorder le clavessin’ (in his Pièces d’orgue, 1695) which indicates explicitly that E and B were treated, by various tuners, as ‘foible ou forte’. It happens that Mersenne’s inadvertent novelty was musically opportune because the cumulative lowering of E would more than achieve, on behalf of D, that which Schlick’s temperament had achieved on behalf of G, albeit at the cost of rendering E–G slightly ‘darker’ than the A–C of Schlick’s temperament. It may further be argued that Louis Couperin’s use of E and even B (as in ex.10) differs from that of his teacher Chambonnières (ex.11), the older man’s music requiring a regular mean-tone temperament while the younger found an opportunity for chiaroscuro in the kind of tuning inadvertently implied by Mersenne. Thus Couperin’s long G minor Passacaille, with its recurring bass line G–F–E–D, may gain a dimension of structure as well as expressiveness when G–B beats about eight times per second but ‘resolves’ to a pure or nearly pure F–A, and then E–G, beating about ten times per second, likewise yields to a more euphonious D–F; and this would represent a significant stylistic departure from Frescobaldi’s music in the same genre, which was known to Couperin. But when inferences are thus drawn beyond what can be proved by documents, a careful assessment – in this case requiring the use of accurately reconstructed 17th-century instruments – must be supplied by impartial judges.

In 1697 Andreas Werckmeister suggested that organists unwilling to adopt his circulating temperament (see §7 below) or to install a split key with separate pipes for E and D might compromise by tuning E down to serve for both notes.

Composers like Samuel Scheidt (1587–1654) and his contemporaries used D enough to tempt any organist without the split key at his disposal perhaps to consider such a makeshift adjustment of the temperament.

Temperaments

5. Equal temperament to 1735.

Although no Renaissance keyboard musician is known to have advocated or adopted equal temperament, it appears to have been used on fretted instruments such as the lute and viol at least since the early 16th century (see §9 below). A line of theorists from Vicentino (1555) to Mersenne and beyond took for granted that fretted and keyboard instruments were incompatible because of their distinct styles of intonation. The development of methods for calculating or approximating the intervals of equal temperament has been traced in J.M. Barbour’s dissertation (1932) and summarized in Tuning and Temperament (1951), where he wrote, ‘The simplest way … is to choose a correct ratio for the semitone and then apply it twelve times’. The ratio 18:17, familiar to theorists from well before the Renaissance and recommended by Vincenzo Galilei in 1581 for equal temperament on the lute, corresponds mathematically to a semitone of 99 cents, virtually indistinguishable from the 100-cent semitone of equal temperament. Therefore the theoretical refinements of a Zarlino (1588) or a Stevin (c1600) may have had less bearing than one might imagine on the historical status of equal temperament in musical practice: an essentially equal temperament was feasible in practice before those theoretical refinements were achieved, and such compositions as Adrian Willaert’s famous Quid non ebrietas (published in 1530) or Francesco Orso’s setting (1567) of Petrarch’s Il cantar nuovo indicate that some 16th-century composers appreciated the enharmonic advantages of equal temperament (see §11 below) which its advocates have always emphasized. In 1603 G.M. Artusi attributed to the unnamed opponent whom he criticized for certain modern tendencies (Monteverdi) a mathematical theory of intervals approximating to equal temperament and justifying the use of diminished 4ths and 7ths in vocal music (Lindley, 1982). The practical history of equal temperament, then, is largely a matter of its refinement in various respects and its gradual acceptance by keyboard musicians from the late 1630s, when Frescobaldi endorsed it, to the 1870s, by which time even the conservative English cathedrals were won over.

Zarlino in 1588 attributed the following prophetic arguments to Girolamo Roselli, abbot of S Martino delle Scale in Sicily:

This way of dividing the diapason or octave into 12 equal parts … could alleviate all the difficulties of singers, players and composers by enabling

them generally … to sing or play … DO–RE–MI–FA–SOL–LA upon whichever of the 12 notes they wish, touring through all the notes, making, as he [Roselli] says, a circular music; hence all the instruments will be able to keep their tuning and be in unison, and organs, as he says, will be neither too high nor too low in pitch.

About 50 years later an ‘old man in rags’, who had spent most of his life in Sicily and Calabria and knew ‘nothing except how to play the harpsichord’, retired to Rome and made a stir by advocating equal temperament on the harpsichord and even inducing Frescobaldi, with the aid of ‘frequent and gratuitous beverages’, to recommend it for the organ in Bernini’s new apse at S Lorenzo in Damaso. The malicious details of this story are due to G.B. Doni (in his book of 1647 and in a letter to Mersenne of February 1640), who prevailed upon Cardinal Francesco Barberini to ignore Frescobaldi’s advice. The renovated apse, with ‘doi bellissimi organi’ in mean-tone, was inaugurated in August 1640 (and witnessed, towards the end of the century, performances by Corelli under the patronage of Cardinal Ottoboni). But already in April 1638 Doni had written to Mersenne that Frescobaldi failed to grasp the difference between major and minor semitones (‘ne scait pas ce que c’est semiton majeur ou mineur’) – an unlikely accusation to make of a former pupil of Luzzaschi and yet perhaps a fair indication of Frescobaldi’s attitude towards niceties of intonation. Whether his magnificent Cento partite sopra passacagli (1637) were intended for equal temperament or for a harpsichord with split accidentals for D/C as well as G/A and D/E, the influence of Frescobaldi’s acceptance of equal temperament is apparent in the later keyboard music of Froberger, who was his pupil in Rome when the old Sicilian harpsichordist was there.

Froberger was not the first north European to use equal temperament on keyboard instruments. In 1637 Mersenne said that the engineer Jean Gallé had ‘accommodated this tuning to the organ and spinet’. By 1645 Gallé or someone else ‘very learned in mathematics’ had persuaded some ‘honest men’ in Paris to use equal temperament, and the instrument maker Jean Denis had been told, to his dismay, that perhaps he would not disapprove of it on the harpsichord so vehemently if he were accustomed to the sound.

It was not mere conservatism that prompted most Baroque keyboard musicians to resist or ignore the suggestions of a Stevin or a Mersenne that they consider adopting equal temperament, but rather their appreciation of the virtues of the feasible alternatives: regular mean-tone in the early 17th century, certain irregular temperaments thereafter. The same interest in timbre and sonority that nourished the Baroque refining of wind and string instruments must also have nourished an interest in the sensuous qualities of relatively subtle tunings. Some representative early 18th-century views are

summarized in the following passage from Neidhardt (1732):

Most people do not find in this tuning that which they seek. It lacks, they say, variety in the beating of its major 3rds and, consequently, a heightening of emotion. In a triad everything sounds bad enough; but if the major 3rds alone, or minor 3rds alone, are played, the former sound much too high, the latter much too low. … Yet if oboes, flutes & the like, and also violins, lutes, gambas & the rest, were all arranged in this same [tuning], then the inevitable church- and chamber-pitch would blend together throughout in the purest [way]. … Thus equal temperament brings with it its comfort and discomfort, like blessed matrimony.

In the late 17th century and early 18th, however, a circle of German theorists became interested in equal temperament, including Werckmeister, Meckenheuser, Neidhardt and Mattheson. The wave of interest that they represent never thereafter lost momentum, although most of the best German organ builders are said to have resisted until after the generation of Gottfried Silbermann and Wender (Mattheson, 1722–5). In England the builder Renatus Harris, wishing to discredit the use of split accidentals by his competitor 'Father' Smith, induced John Wallis to publish in the Philosophical Transactions of 1698 an article 'On the Imperfections of the Organ' (Williams, 1968). Though admittedly 'little acquainted' with the instrument, Wallis said that equal temperament had been 'found necessary (if I do not mistake the practice)' on organs. This exaggerated claim appears to indicate that equal temperament in any case was no longer unthinkable for organs. And when Brossard in 1703 remarked on the existence of two schools of opinion regarding temperament in practice, he did not, as so many had done before him, associate equal temperament with fretted instruments and its alternatives with keyboard instruments.

Special comment is warranted by the fact that equal temperament is often particularly associated with the name of Werckmeister, or with John Bull's long Ut-re-mi-fa-sol-la in the Fitzwilliam Virginal Book (no.51). Bull's piece does use all five sharps in some sections and all five flats in others, but never both a sharp and a flat in the same section; it was most probably conceived for arcicembalo. Werckmeister's attitude at the end of his life is summarized in a book published posthumously (1707) where in effect he apologized for not having included equal temperament among the various circulating temperaments for which he had earlier published a monochord diagram. (The incompetent engraver, he said, had complained about dividing the narrow space of a comma into 12 parts.) He quite approved of equal temperament, yet was willing 'to have the diatonic 3rds left somewhat purer than the other, less often used ones', a procedure for which he had expressed clear preference in his earlier writings (see §7 below).

6. Regular mean-tone temperaments from 1600.

The late Renaissance system of church modes or tones was suited to the harmonic dimensions of a 12-note mean-tone palette (from E to G in the chain of 5ths) as long as V–I cadences were not required in the Phrygian mode (E minor) and as long as the Dorian, with its often flattened sixth degee, was not transposed more than one place down in the chain of 5ths to G minor. Cadences to E could be accommodated by the use of a split accidental on the keyboard to provide D as well as E; and a split accidental for A and G was also often provided (see, for instance, Compenius). But the growing popularity, from the late 17th century, of more expansive modulations rendered regular mean-tone temperaments musically problematical well before the end of the Baroque era, although the old tunings remained familiar on many organs.

Michael Praetorius in his De organographia (1618) prescribed exclusively 1/4-comma mean-tone for keyboard instruments, a tuning later referred to by German theorists as the ‘Praetorianische Temperatur’. In France Mersenne, relying heavily upon Salinas’s De musica, also neglected to mention any shade with major 3rds larger than pure; he described 1/4-comma mean-tone as ‘la manière d’accorder parfaictment les Orgues ordinaires’. The pre-eminence of these authorities and Zarlino caused 1/4-comma mean-tone to be regarded by many subsequent writers as the exemplary ideal of mean-tone temperament and even of Renaissance and Baroque keyboard tunings in general. An indication of its use on 17th-century German organs lies in Werckmeister’s assertion (1697) that an instrument would be converted to his circulating temperament, in which the 5ths C–G–D–A are tempered 1/4-comma, by resetting only some of the pipes. In the late 17th century and the 18th the increasing popularity of tierce ranks in mixture stops promoted the brilliance of 1/4-comma mean-tone, with its pure major 3rds, on the organ.

But mean-tone temperament with major 3rds larger than pure also flourished. Cerone attributed it in 1613 to master organ builders. Lemme Rossi (1666) described 1/5-comma and mentioned 2/9-comma mean-tone. The instructions of Jean Denis (1643), a professional harpsichord tuner, specify no particular shade of mean-tone, prescribing only ‘good’ 3rds together with 5ths tempered by ‘un poinct’; but in 1707 and 1711 the acoustician Joseph Sauveur, using an elaborate monochord to compare 1/4-, 1/5- and 1/6-comma mean-tone, reported that organ and harpsichord makers adhered more closely to 1/5-comma mean-tone than to the other two forms, even though ‘les musiciens ordinaires’ used 1/5-comma mean-tone. W.C. Printz in 1696 described the same three shadings and also 2/9-comma mean-tone, which he said was ‘even earlier’ (‘noch eher’) than 1/4-comma. Loulié in 1698 said that 1/5-

comma mean-tone was ‘better and more in use’ than any other temperament. Sorge in 1748 attributed the use of 1/6-comma mean-tone to Gottfried Silbermann (and a posthumous book of Sorge (1773) confirmed the presence on two ‘especially good’ Silbermann organs of a ‘horribly large beating 5th, G–D, along with four unbearably barbaric major 3rds’). J.-B. Romieu in 1758 expressed preference for 1/6-comma mean-tone because he liked the relative amount of tempering that it allots to 5ths and 3rds. The same criterion led Giordano Riccati in 1762 to give preference to his own 3/14-comma system (among regular temperaments).

Mean-tone with major 3rds smaller than pure seems to have disappeared from normal practice, although Cerone reproduced Zarlino’s instructions of 1558, and Cima’s instructions (1606) confused it (even more plainly than Aaron’s of 1523) with 1/4-comma mean-tone. Lemme Rossi, Mersenne and Printz described it, and in the 18th century Henfling (1710) and Smith (1749) advocated it as an innovation. More recently Kornerup sought to champion it in the 1930s, and in 1948 A.R. McClure published a good account of its sound. According to Mersenne, Titelouze had a harpsichord with 19 notes per octave tuned in equal microtones – the equivalent, as it happens, of 1/3-comma mean-tone. Salinas had published tuning instructions for 1/3-comma mean-tone applicable to such an instrument, but it is not certain whether the 19-note harpsichord built by Pesarese for Zarlino or the one built by Elsasz for Luython and described by Praetorius were tuned thus. Costeley published in 1570 a chanson spirituelle, Seigneur Dieu, ta pitié, which he had composed as an exercise in the use of the 19-note scale (Levy, 1955). In the 20th century interest in the 19-note equal division was developed by, among others, Yasser (1932), Handschin (1927) and Mandelbaum (1961).

For various shades of mean-tone the corresponding schemes of dividing the octave into equal microtones were worked out, with the aid of logarithms, during the 17th century. The correspondence between 1/4-comma mean-tone and the 31-part division was described clearly in publications by Lemme Rossi (1666), Joseph Zaragoza (1674) and Christiaan Huygens (1691). Zaragoza also equated the 19-part division with 1/3-comma mean-tone. Joseph Sauveur (1701) matched the 43-part division (which Zaragoza had mentioned) with 1/5-comma mean-tone, and the 55-part division (illustrated in a circular diagram by António Fernandez in 1626) with 1/6-comma mean-tone. This kind of theoretical speculation continued in the 18th century. By 1637 Gallé had properly reckoned the intervals of just intonation in terms of the 53-part division, similarly favoured by Isaac Newton in 1665 and Nicolas Mercator in the 1670s.

When an 18th-century writer advocated one of these schemes he is much more likely to have been referring to a general theoretical model – a shade of

mean-tone (the French term was ton moyen) regarded as an ideal of intonation – than to an experimental keyboard instrument. In this sense the 55 division, corresponding to 1/6-comma mean-tone, was particularly eminent. Not only did Sauveur attribute it to ‘ordinary musicians’, but Mattheson (1722–5) was familiar with it and Sorge (1748) labelled it ‘Telemann’s system’. In this scheme the whole tone comprises nine ‘commas’; but not every reference to that feature necessarily implies the 55 division, as the same feature characterizes the nearly Pythagorean 53 division, which happens to contain virtually pure 3rds as well as 5ths and which had been referred to in a Pythagorean context by Italian theorists since the 15th century (e.g. Anselmi, 1434). Neither Praetorius (1618) nor Nassarre (1723–4) had in mind 1/6-comma mean-tone when referring to the whole tone as made up of nine commas, and one may entertain doubts in the case of other writers, like Brossard (1703) or Tosi (1723), who were not specialists in the theory of microtonal scales. The status of 1/6-comma mean-tone in performing practice might better be confirmed by systematic research into 18th-century woodwind instruments that survive unaltered. Certainly the expressive semitones and harmonic 3rds and 6ths in ex.12, the opening of Lully’s overture to Bellérophon in a 17th-century keyboard transcription, are ill-served by 1/4-comma mean-tone

Some scholars have assumed that Baroque harpsichordists habitually retuned wholesale the accidentals on their instruments in order to produce various dispositions of regular mean-tone for music in various keys (Barbour and Kuttner, 1958; Rayner, 1969). But no Baroque musician or theorist other than Cima (1606) is known to have described this procedure; and evidently the standard 17th-century 12-note disposition (E–G) was used by some late 17th-century and 18th-century musicians as if it were a circulating temperament. Apparent references to this practice can be found in the writings of Christiaan Huygens (?1670s), Werckmeister (1700), Romieu (1758) and Bédos de Celles (1766–78), in the fourth edition of the Encyclopaedia Britannica (1810) and elsewhere. As late as 1847 I.F. Holton in New York wrote:

In Unequal Temperament some of the chords are very good, while the aggravated dissonance of others, called by tuners the WOLF, imparts a peculiarity to the keys in which it occurs, much admired by certain musicians … These predilections … must be chiefly attributed to fancy and prejudice. Some inequality of temperament may be preferable, but no key ought to he made so bad as to give it a character for harshness.

Similar opinions had been expressed throughout the 18th century.

Extant specimens of Baroque carillon are said to be tuned to some form of mean-tone; in view of their inharmonic timbre this is a remarkable indication

of the precision in tuning and control of timbre achieved by the Hemonys and other master bellfounders.

Temperaments

7. Irregular temperaments from 1680.

The most characteristic type of 18th-century keyboard tuning was an irregular temperament with no wolf 5th but with the 3rds in the C major scale tempered lightly, more or less as in some form of mean-tone temperament; most of the 3rds in ‘modern’ keys (such as B major, A major or F minor) were thereby rendered distinctly more impure than in equal temperament. As a modulation of triadic harmonies moved about the circle of 5ths the amount of tempering in the 3rds would thus change, in a fairly unabrupt fashion, according to whether one was closer to the front or back of the circle as shown in fig.2. The degree and exact pattern of the differences might vary to suit taste and circumstance without forfeiting this principle; in fact different instruments require different quantities to achieve equivalent results. But there is occasional evidence of a tendency for the E major triad to be tuned approximately as in equal temperament. Concomitant to variously tempered 3rds were diverse sizes of semitone, the largest being E–F and B–C and the smallest C–D and perhaps F–G (or E–F). Hence the major keys with few sharps or flats had the most resonant and limpid triads but the least keenly inflected leading notes. In minor keys the effects were more intricate, E minor for instance having a sharper leading note but a less harsh tonic triad than F minor, a key often remarked on (e.g. by M.-A. Charpentier, c1692; Mattheson, 1713; Rousseau, 1768; Gervasoni, 1800) for its dark qualities.

Routine sequences as in ex.13 (from a sonata of G.B. Platti) gain savour in this kind of tuning, and more elaborate sequential manipulations are enhanced. In lieu of an extensive discussion of key character (see Steblin, 1983), ex.14 (the opening of an organ prelude of J.C.F. Fischer) may represent the fact that in the key of A major, D is often a particularly tender note by virtue of its low intonation and its affinity in part-writing to C (which is inflected high in relation to A and D). Shadings of this sort lend an unimaginable dimension of beauty to such lavishly flat-laden pieces as J.S. Bach’s chorale prelude O Mensch, bewein’ or the Adagio of Beethoven’s ‘Pathétique’ Sonata. Qualities of nuance in various keys created by this kind of tuning contributed much to the beauty of the Baroque French harpsichord and its music by such masters as d’Anglebert and François Couperin, who according to J.-J. Rousseau ‘proposed and abandoned’ equal temperament (‘Tempérament’, in the Encyclopédie, 1768). Handel’s harmonically daring recitatives are also brilliantly enhanced, and the static tendency of the harmony in some of his arias (compared with Bach’s) is rendered more logical. William Croft (1700)

was evidently the first English keyboard composer to exploit the resources of this type of intonation (Meffen, 1978).

Except for Werckmeister's harpsichord tuning instructions of 1698 (summarized by F.T. Arnold, 1931), no Baroque prescription in German is known to have called for any 5ths larger than pure or, consequently, any 3rds less pure than Pythagorean 3rds. In German tunings the 5ths among the naturals averaged a heavier degree of tempering than those among the accidentals, the latter tending in fact to be pure. Some German writers characterized as 'good' any temperament well suited to harmony involving all 24 major and minor keys, thereby including equal temperament; but others regarded equal temperament as distinctly less 'good' than irregular temperaments of the type described here (see Well-tempered clavier).

French tuning instructions characteristically required two or three 5ths at the back of the circle of 5ths to be tempered slightly larger than pure (most probably A–E–B–F; see §4 above), thus producing a more pronounced difference in size and quality between the 3rds D–F–A–C and the 3rds among the seven diatonic notes. This kind of tuning was often referred to by 18th-century French musicians as the 'ordinary' or 'common' temperament, although some occasionally confused it with regular mean-tone (e.g. Bédos de Celles, 1766–78) or with some tuning similar to the irregular temperament described in §4 above (e.g. Corrette, 1752). Hence it is difficult to be certain exactly what shade of temperament Ozanam had in mind when he wrote in 1691:

Whatever precaution we might take in tuning our instruments to render all the chords equal, there is always left therein some inequality that causes us to notice a je-ne-sais-quoi of sadness or gaiety, of the melodious or the harsh, which [in turn] makes us distinguish one key from another by ear.

Yet Ozanam's distinction between 'natural' and 'transposed' modes confirms that the inequalities in question were distributed not at random but in a pattern consistent enough to allow the keys to be identified by ear according to their intonational inflections. Rousseau also wrote, in 1768, that the keys could thus be identified by ear, in the course of discussing a circulating form of the 'ordinary' temperament as described by Rameau in 1726. Rameau's instructions were accompanied with the following remarks:

The excess of the last two 5ths and the last four or five major 3rds is tolerable, not only because it is almost insensible, but also because it occurs in modulations little used – except for when one might choose them on purpose to render the expression more keen etc. For it is good to note that we receive different impressions from intervals in keeping with their different

[degree of] alteration. For example the major 3rd, which [in its] natural [state] excites us to joy, as we know from experience, impresses upon us ideas even of fury when it is too large; and the minor 3rd, which [in its] natural [state] transports us to sweetness and tenderness, saddens us when it is too small. Knowledgeable musicians know how to exploit these different effects of the intervals, and give value, by the expression they draw therefrom, to the alteration which one might [otherwise] condemn.

In 1737 Rameau changed his views (see §8 below); but in that respect d'Alembert (1752) took a neutral position in what had evidently become a controversial matter. Remarkably lucid comments on the relation between irregular temperaments and modulation (in virtually the modern classroom sense of the term) appeared in the Histoire de l'Académie royale des sciences at Paris in 1742. The preference of some composers for the 'transposed modes' had been discussed in an equally urbane article in the Mémoires de Trevoux (1718) which suggested that while it was arbitrary to give specific affective labels to particular keys, the extreme keys were, because of their tuning, comparable with a ragout with more vinegar and spice than an ordinary one or one conducive to good health.

Mattheson in 1720 published a book of reflections on this article and mentioned favourably the work of Neidhardt, who soon became the most elaborate technician of subtle shades of 'good' temperament (1724 and 1732). Later French and English advocates of a fairly subtle irregular tuning included Mercadier de Belesta (1776), Suremain-Missery (1793), Thomas Young (1800) and Jean Jousse (1832). Sorge (1744 and 1746) and J.H. Lambert (1774) also described such tunings, but were themselves content with equal temperament. These finer tunings are usually the most appropriate for late 18th-century music. F.A. Vallotti, maestro at S Antonio, Padua, from 1730 to 1779 and a highly regarded church composer and organist, designed a moderately subtle tuning (with the six 5ths among the diatonic notes each tempered by 1/6-comma) which is one of the simplest of its type (Lindley, 1981), although Werckmeister's equally simple scheme for the organ (in which the 5ths G–D–A–E and B–F are each tempered by 1/4-comma) sounds more fitting in some late 17th- and early 18th-century German organ music.

There is evidence, however, that a less subtle degree of inequality in some Italian and English as well as some French tuning, persisted in the 18th century. Giordano Riccati, a physicist who corresponded extensively with Vallotti, published in 1762 a scheme which he suggested was in keeping with current practice, and in which A–E was larger than pure by some 2/5 of the Pythagorean comma. (The six diatonic 5ths were each tempered 3/17; of the syntonic comma, while E–B–F and B–F–C–G were as in equal temperament.) A contemporary set of manuscript instructions preserved at the Conservatory of

Padua refers to the sequence of 4ths B–E–A as tempered smaller than pure, and that of E–B–F–C as pure. Metastasio referred in a letter of 1770 to the use of one 5th, ‘which they call allegra’, tuned larger than pure by ear. In England, irregular schemes of similar crudity were prescribed by Arthur Wood (c1730), J.C. Petit (c1740) and William Hawkes (1805).

Among the late 18th- and early 19th-century Italian and English accounts of irregular temperaments may be mentioned those of Gervasoni (1800 and 1812), Barca (1809), Serassi (1816), Asioli (1816), William Jones (i) (1784), Cavallo (1788 and 1803), Robison (1801), Stanhope (1806), Kollmann (1806 and 1823) and Callcott (1807). The American Journal of Science began publication in 1818 with an account of the attempt by Alexander Fisher, a Yale mathematician, to derive an ideal model of temperament from a statistical reckoning of the use of different key signatures in 1600 compositions, and of the use of each major and minor triad in 200 compositions ‘taken promiscuously from all the varieties of music for the organ’. Fisher acknowledged, but made too little allowance for, the crucial fact that ‘making the aggregate of dissonance … the least possible … [would] render the harmony of the chords very unequal … a disadvantage’.

More important than the work of such theorists is the evidence, which can be outlined here only briefly, that none of the masterworks of late Baroque and Classical German keyboard music was in fact created in a prevading ambience of equal-tempered intonational sameness among the various triads and keys, although some forward-looking composers did tend, like C.P.E. Bach (see §8 below), to think in such terms. In 1697 Werckmeister had written:

Now if all semitones, tones, 3rds, 5ths, etc. had the same size and [equivalent] beating, people would take little pleasure in transpositions: for example, if the Dorian is transposed a second into either C or E: such transpositions produce notable alterations and excitement. This is brought about not so much by the change in pitch level as by the reordering of the tones and semitones, and also the [varied] beating of the concords.

Heinichen in 1728, while ridiculing Mattheson’s propensity to ‘assign specifically to this or that key the affect of love, sadness, joy, etc.’, acknowledged that

in general it may well be said that one key is more fitting than another for expressing affects [at large]; and in today’s good temperaments (I am not referring to old organs) the keys with two or three flats or sharps in their signatures emerge, especially in the theatrical style, as the most beautiful and expressive. For this reason I would not even support the invention of the long-sought clavier in just intonation were it to become practicable.

Kirnberger held that a good temperament ‘must not injure the variegation of the keys’ (1776–9), and his disciple (in this regard) Tempelhof in 1775, while acknowledging that any key could express any affect, held nonetheless that in a good temperament each key would do so in its own particular way (‘auf eine ihnen angemessene Art’) and that without such expressive resources music would be ‘nothing more than a harmonious noise that tickles the ear but leaves the heart slumbering away in a disgusting indifference’. In 1780 the polymath J.J. Engel, in a book dedicated to Reichardt, placed the choice of key before melody and harmony as a resource of musical portrayal, and said that among the major keys, C and A differed most since the steps of their scales differed most.

In 1784 Cramer’s Magazin der Musik reported that Clementi used a tuning in which C–E was tempered ‘ein klein wenig hoch schwebend’ (‘beating, slightly high’), E–G ‘sehr hoch’ (‘very high’) and A–C ‘noch höher’ (‘even higher’). In 1785 Mozart’s pupil Thomas Attwood recorded in his notebook that G was a note which ‘the Harpsichord has not, but all other instruments have’ (Chesnut, 1977). According to A.F. Schindler (1860), Beethoven in his last years maintained a keen interest in the expressive characteristics of different keys and suggested that they were most apparent in piano music. It is unclear to what extent Beethoven may have attributed the differences to acoustical factors, but his piano music does in fact benefit from an 18th-century unequal temperament (Lindley and others, 1997, chap. 5).

In 1826 the leading champion of Viennese Classical music in Italy, Peter Lichtenthal, wrote that equal temperament ‘cannot subsist’ or else the keys would lose their character and ‘one could equally [well] compose a nocturne in A minor or a military blare in A’ – an opinion that was excised, however, in Dominique Mondo’s French translation 13 years later. Yet the late Baroque associations of different qualities with different keys cast their shadows far into the 19th century. This legacy warrants investigation. A good point of departure is that Schubert’s piano music benefits from an unequal well-tempered tuning if the nuances are subtle enough that C–E is tempered more than half as much as in equal temperament (rendering E suitable to such melodious uses as shown in ex.15) and D–F is no nearer in size to a Pythagorean 3rd than to an equal-tempered one (since Schubert used very freely the key of D major). Equally telling is the curious fact that D minor, the most eminent of keys in Baroque keyboard music and one that to a large extent retained its old mean-tone-like sound in the 18th-century irregular temperaments, was the key least favoured by Chopin, except in the last and most magnificent of his 24 preludes.

Temperaments

8. Equal temperament from 1735.

In his Génération harmonique (1737) Rameau endorsed equal temperament and, by way of retracting his own views of 11 years before, introduced a new argument in its favour:

He who believes that the different impressions which he receives from the differences caused in each transposed mode by the temperament [now] in use heighten its character and draw greater variety from it, will permit me to tell him that he is mistaken. The sense of variety arises from the intertwining of the keys [l’entrelacement des Modes] and not at all from the alteration of the intervals, which can only displease the ear and consequently distract it from its functions.

Distracting the musical ear from its proper functions is an unpardonable fault in a tuning. Rameau’s argument might well have applied more palpably in France than in Germany, if French unequal tunings were, as they generally appear to have been, less subtle than their German counterparts. Rameau’s authority as a musician was such that the 1749 register of the Paris Académie Royale des Sciences could state, ‘M. Rameau assures us that experience is not opposed to the temperament that he proposes; and in this regard he has earned the right to be taken at his word’. Equal temperament continued to be identified with his name throughout the 18th century in France and occasionally in Italy as well.

In Germany J.N. Ritter, perhaps the most important organ builder in Franconia at the middle of the century, is said to have used equal temperament. Among theorists advocating it Barthold Fritz is especially important, despite the crudeness of his tuning instructions, because in the preface to the second edition (1757) of his Anweisung (1757: the title may be translated as ‘Method for tuning claviers, harpsichords and organs, in a mechanical way, equally pure in all keys’), he reported that C.P.E. Bach had found ‘in my few pages everything … that was necessary and possible’ for a good tuning. C.P.E. Bach’s own advice (1762) for improvising a fantasia mentioned temperaments: on the organ, he said, ‘one must restrain oneself in chromatic passages; at least they should not be advanced sequentially, because organs are seldom well tempered. The clavichord and the piano are the most fitting instruments for our fantasia. Both of them can, and must, be tuned pure’. For Marpurg and others ‘rein’ (‘pure’), which C.P.E. Bach himself here distinguished from ‘gut’ (‘good’ or ‘well’), became a catchword in arguments favouring equal temperament (or at least not a purposefully unequal one). Fritz’s title shows how it came to serve in that capacity; once equal-tempered 3rds were considered acceptable, then a tuning with certain 3rds tempered more heavily could be described as relatively impure. Since C.P.E. Bach was

sufficiently concerned to give not only a warning about the limitations of mean-tone but also emphatic advice about the tuning of the clavichord and piano, the fact that he did not recommend exploiting the inflections of a circulating unequal temperament in a genre which, by his own definition, ‘modulates into more keys than is customary in other pieces’ suggests an indifference to those inflections. When C.P.E. Bach spoke of ‘remote’ keys, he meant keys remote from the tonic key, not keys remote from C major or D minor. His compositions, for instance the great rondos from the collections für Kenner und Liebhaber, reflect this neglect of the concept expressed in fig.2 above; and his favourite instrument, the clavichord, was the least likely of all normal keyboard instruments to display to much advantage the niceties of an irregular temperament. If the music of any leading 18th-century German composer ought to be performed in equal temperament, C.P.E. Bach is the best candidate.

No unequivocal conclusion can be established as to the attitude of his father, J.S. Bach, towards the relative merits of equal temperament and a mildly unequal one. On the basis of evidence such as applied above to C.P.E. Bach, Barbour showed (1932) that J.S. Bach would probably not have held a dogmatic opinion (a view rejected by Rasch, 1981). Barbour’s later statement (1951, p.196) that ‘much of Bach’s organ music would have been dreadfully dissonant in any sort of tuning except equal temperament’ is a silly exaggeration, due perhaps to the fact, which he mentioned in a letter of 1948 to A.R. McClure, that Barbour had never heard any keyboard temperament other than equal temperament. John Barnes (1979) investigated the ‘48’ in a fairly subtle type of irregular temperament (see Well-tempered clavier, table 1) and found that the peculiarities of the various keys in that tuning are nicely suited to or accommodated by the music. According to Marpurg (1776), Kirnberger scrupulously reported that Bach, his teacher, had instructed him to tune all major 3rds larger than pure – thus ruling out any unsubtle irregular temperament (such as used by Kirnberger himself). One could readily believe that Bach sometimes exploited the qualities of a particular key as inflected in a typical irregular temperament, sometimes merely accommodated what he knew was likely to be the kind of tuning his published music would be played on, and sometimes – for instance, in the concluding ricercar of the Musical Offering – ignored completely the possibility of intonational shadings.

The most vigorous and articulate late 18th-century champion of equal temperament seems to have been F.W. Marpurg, whose Versuch über die musikalische Temperatur was published in 1776 but who had already advocated equal temperament in his Principes du clavecin (1756). Although capable of meretricious reasoning, he presented, in greater detail than Rameau, numerous forceful arguments, some of which were rendered so valid by historical circumstance that during the 19th century equal temperament

became the standard keyboard tuning and, in the West, a widely followed norm of intonation in general. Marpurg (1776) knew that a composer might select a key for reasons ‘that have nothing to do with temperament’; and he saw (as did Tiberius Cavallo in 1788) the advantages of equal temperament in ensemble music, where

so long as not all the instruments playing together, and the vocal parts as well, are intoned in the most perfect agreement in one kind of [irregular] temperament, the composer must obtain the character of his piece, the building up of an emotion, and the strength of expression, from sources quite other than the creative powers of the tuning hammer or cone.

His encounters with the tuning schemes of Kirnberger and C.L.G. von Wiese (see Eitner), as well as his knowledge of the writings of Werckmeister, Neidhardt, Lambert and others, showed him that:

There is only one kind of equal temperament but countless possible types of unequal temperament. Thus the latter opens up to speculative musicians an unstinting source of modifications, and since every musician will readily invent one, the result will be that from time to time we shall be presented with a new type of unequal temperament, and everyone will declare his own the best.

In short, he gave equal temperament decisive preference on both of the counts envisaged by Fontenelle, who had written in 1711: ‘After these motley combats, one system will become victorious. If fortune favours the best system, music will gain thereby a real advantage; and in any case it will at least profit from the convenience of having the same ideas and the same language accepted everywhere’.

D.G. Türk (1802) extended Rameau’s argument of 1737 cited above by suggesting that a sameness of quality among the various keys would contribute to unity of character in a composition. Influential musicians supported equal temperament in Italy (Asioli, 1816) and England (Crotch, 1812 and, invoking J.S. Bach, 1833). Hummel’s Anweisung zum Piano-Forte Spiel (1828) concluded with a discussion of tuning that justified ignoring the old, unequal temperaments on the grounds that they presented, particularly for the many novice tuners brought into the trade by the popularity of the piano, greater difficulties than equal temperament and that these difficulties were aggravated critically by the burden of tuning, on modern pianos, three heavy strings for each note instead of two thin ones as on older instruments. Jousse, in a book on piano tuning (1832) dedicated to W.F. Collard, expressed preference for a subtly unequal temperament, but Claude Montal (1834) gave instructions solely for equal temperament on the piano. In the 1840s Alfred Hipkins persuaded the Broadwood firm to tune their pianos in equal

temperament, which he must have used when tuning for Chopin in London in 1848. Cavaillé-Coll (in his maturity) and contemporary German organ builders used it; almost all the English organ builders resisted until after the Great Exhibition of 1851, but their notebooks show that from the mid-1850s until the 1870s, rebuilt or reconditioned church organs were usually raised to the current concert pitch and converted to equal temperament (see Mackenzie, 1980).

A relatively late development was the widespread use of more refined tuning procedures than those of Rameau or Fritz, in order to guarantee uniformity among the 3rds and 6ths. (In reality this can seldom be achieved by tempering all the 5ths and 4ths alike or by matching unisons with a monochord. See Equal temperament and Tuning.) Sorge’s method (1749, republished by Marpurg, 1756, Roesner, c1765, and Bossler, 1782) was to temper a chain of major 3rds (C–E–G/A–C) before tempering any of the 5ths, and after setting the 5ths in three chains of four each (rather than one chain of 12), to check whether all 12 major triads, ascending chromatically, ‘are equally sharp to one another’. A sufficiently exact yardstick for ‘equally sharp’ gained currency during the 19th century – that each major 3rd or 6th should beat no slower than the one below and no faster than the one above.

Equal temperament in this more exact sense is virtually considered an inherent characteristic of the modern concert piano. Indeed the ideals of sonority in the acoustic design of the modern piano and in all but the more radical forms of modern pianism are as intimately bound to the acoustic qualities of equal temperament as any previous keyboard style ever was to its contemporary style of intonation. The enharmonic facility of Brahms or Fauré, the hovering sonorities of Debussy, the timbral poise of Webern, the slickness of the most urbane jazz chord progressions, all rely implicitly on the hue of equal temperament as much as on the other normal characteristics of the instrument’s tone. An 18th-century tuning usually sounds as inappropriate for this music as the piano would seem visually if its glossy black finish were replaced by an 18th-century décor.

Temperaments

9. Fretted instruments.

Insofar as the relation between performing practice and compositional style is concerned, the history of temperaments on fretted instruments in Western art music since the mid-16th century has been simpler than on keyboard instruments, for two reasons: the placing of the frets and tuning of the open strings does not impose an exact intonation of the scale on the player as definitively as the harpsichord or organ tuner’s handiwork does; and the use of distinctly unequal semitones in the fretting scheme is likely to be

problematical as each fret runs under all the strings at once.

Lute and viol strings were traditionally made of gut (although from the late 17th century the lowest strings were likely to be overspun). Inconsistencies in this material are greater than in carefully drawn wire for harpsichord strings. Even Hubert Le Blanc acknowledged, in his enthusiastic Défense de la basse de viole (1740), that ‘the rules for gut strings are variable. Two strings of the same thickness [grosseur], as clear as rock crystal, make the 5th at a considerably different degree forward and back’. Practical considerations of this kind tend to overshadow the embodiment of any precise model of a tempered scale to a greater extent than on the harpsichord (where imperfections in the strings are less telling) or the organ. Moreover, all the mathematical schemes for determining the position of the frets were based on measuring off certain portions of the neck, as if an alteration in string length were the only effect produced when the player presses the string against the fret: but the concomitant increase in the string’s tension is significant enough to reduce even the most precise geometrical division to a mere preliminary. Several Renaissance and Baroque musician-theorists who discussed fret placing remarked that one must make, or that players did make, further adjustments by ear.

Thus a mathematical procedure for determining the position of frets on a lute or viol had a rather different kind of significance from that of a monochord prescription. Monochord schemes often embodied a precise model of intonation which the performer or instrument maker or tuner was supposed to transfer into practice by whatever techniques were appropriate. The fact that Renaissance and Baroque theorists developed the use of irrational numbers in their monochord schemes is, in large part, evidence of this precise intention. Formulae for marking where to tie a fret on the neck of a lute or viol often involved exclusively rational numbers. The reason is not only that an accomplished player, a person often of quite different educational and social background from many music theorists, would be less likely to know or care about irrational numbers, but also that for the player the numerical measuring was but the first stage in determining the intonation of the instrument. Its function was merely to help place the frets close enough to their final position so that the player could go on to the next stage, that of tuning the open strings by ear and concurrently making slight adjustments in the frets. The intonation of the notes might then be further shaded ad hoc during performance.

In this light one may distinguish four kinds of late Renaissance fretting prescriptions: those with exclusively Pythagorean ratios (e.g. Finé, 1530); those that embody a precise mathematical model of equal temperament but are too elaborate to be of much practical use (e.g. Zarlino, 1588); those that

seem to betray by their complexity an erudite intention, but fail to embody precisely any feasible model of intonation (notably Dowland, 1610; see Poulton, 1972, appx 1); and those simplified for practicability. Among the last type, equal temperament is best represented by Vincenzo Galilei's rule – that the ratio 18:17 should be used for placing each successive fret down the neck of the instrument – a rule that Mersenne said was used by many instrument makers. A less exact approximation, but perhaps adequate for its purpose, could be gained by dividing the 9:8 whole tones of a Pythagorean diatonic scheme into 18:17 and 17:16 semitones, a rule given by theorists as late as Nassarre (1723–4). Ganassi's equally simple viol prescription (1542–3) would have produced, from the nut to the eighth fret, the ratios 24:222/3:211/3:20:19:18:17:16:15, had he not specified that certain frets be shifted up or down by their own width or by half that amount. His accompanying remarks not only emphasize the need for refinements by ear but also refer to the tempering of 5ths for the sake of distinguishing major and minor semitones and for a better sound in chords and in ensemble music. There are corroborating indications that before the second half of the 16th century, approximations of mean-tone temperament may have competed with equal temperament on fretted instruments, and a distinguished modern lutenist (see Dombois, 1974) has found them musically advantageous in some instances. The historical evidence is inconsistent but suggestive.

In mean-tone temperament as in Pythagorean intonation there is a distinction in size between diatonic and chromatic semitones (A–B, for example, being larger than B–B in mean-tone temperament, but smaller in Pythagorean intonation). The inconvenience of maintaining this distinction on fretted instruments is illustrated by the fact that most 16th-century lute music requires the first fret on the third lowest string to provide the note a chromatic semitone above the open string (G on the G string on a lute with the highest string tuned to a') but calls on the same fret to provide a diatonic semitone above the fourth open string (C on the B string).

It would have been difficult for early Renaissance theorists to recognize or approve of the use of equal semitones because until the publication in Latin of Euclid's Elements in 1482, the myth that a whole tone could not be divided into two equal parts was virtually unchallenged among scholars. To demonstrate this premise, theorists would sometimes explain that if a whole tone of ratio 9:8 were divided into two semitones of ratio 18:17 and 17:16, then obviously one of the semitones (18:17) would be smaller than the other. The fact that an 18:17 semitone amounts to 99 cents, virtually the same as the semitone of equal temperament, might give particular significance, however, to certain early 16th-century assertions such as that of Spataro (1521) that 'the lute has minor semitones [for] all its frets' ('el leuto ha tuti li soi tasti semitonii minori'; see Lowinsky, 1956) or of Martin Agricola (1545)

that ‘almost the majority of lute and viol players make all the frets equal to one another … a fret produces the minor semitone’:

… fast das gröste part
Der Lautnisten und Geiger art
Alle bünd machen gleich von ein
… ein bund
Der semiton minus/thut kund

Yet Agricola’s statement implies that in his day some players of fretted instruments did not use equal semitones. Arnolt Schlick (Tablaturen etlicher Lobesang und Lidlein, 1512) and, for the most part, Milán Luys (El maestro, 1536) seem to have avoided those combinations of fingerings that would render inconvenient the use of unequal semitones. The only one of Schlick’s 15 extant lute pieces that uses the first fret on the third string (Nach lust hab ich) does so on no other, while in other respects his music accommodates a fretting with the following succession of semitones as one ascends from the open strings: diatonic, chromatic; diatonic, chromatic; diatonic; diatonic, chromatic; diatonic. (Above each string the intervals provided are: minor 2nd, whole tone, minor 3rd, major 3rd, perfect 4th, diminished 5th, perfect 5th, minor 6th; see fig.3.) To judge by his organ tuning instructions, Schlick’s ear was probably extraordinarily perceptive of such intricacies; he might well have sought to accommodate the use of a mean-tone temperament in his lute compositions.

Milán Luys did not avoid using the first fret to provide G on the G string, but he did exercise circumspection: whereas he would use the second fret for the A in ex.16a or the fourth fret for the G in ex.16b, the first fret would not be required to provide G in any context more conspicuous vertically than that shown in ex.16c. It is true that occasionally (see ex.16d) he required the fourth fret to provide not only the B shown in fig.3 but also an E (instead of the D in fig.3), and similarly with regard to C and F at the sixth fret. Yet a rejection of equal temperament, in which major 3rds are the same size as diminished 4ths, is indicated by the prefatory instructions to one of his fantasias (1536, p.30) to ‘raise the fourth fret a little so that the note of that fret will be strong and not feeble’. It is difficult to be certain just what ‘raise’ and ‘strong’ meant in this instance; but a clearer inference can be drawn from the instruction to adjust the same fret ‘up towards the pegs’ in his setting of Con pavor recordo el moro, in which the fret is used exclusively for notes a major 3rd above the open string. This inference is confirmed obliquely by an instruction of Enríquez de Valderrábano (1547, f.74v) to move the fourth fret ‘slightly down towards the rose’, indicating unequivocally that the pitch of the notes affected, which in this case are all a diminished 4th above the open string, was to be higher than if they had been a major 3rd above the open

string: the major 3rd, one may thus infer, was a smaller interval than in equal temperament. Evidently, however, Valderrábano did not consistently reject the use of equal semitones, as some of his duets require the two vihuelas to be tuned a minor 3rd apart from each other, an arrangement for which the use of unequal semitones in the fretting would be bound to entail some sour unisons.

Bermudo’s comments (1555, ff.103–9) on fret placement and intonation reflect a confusion – which is evident elsewhere in his book and which he shared with Gaffurius, Aaron, Lanfranco and a number of other early 16th-century theorists – between mean-tone temperaments in practice and Pythagorean intonation in theory. Bermudo indicated unmistakably, however, that rather than using equal semitones many vihuelists would set some of the frets at a slant or else ‘not press down the finger equally’ when playing. The latter technique had been referred to ten years earlier by Aaron (1545, f.35v): ‘the [intonation of a] lute can be aided with the finger of the player, by the intensione and remissione of a minute space for the reintegration of its consonance’.

Well before the end of the 16th century it became a commonplace of Italian musical writings that the use of equal temperament was normal for fretted instruments while keyboard instruments were tuned with unequal semitones (i.e. in some form of regular mean-tone temperament); and this distinction was carried on through most of the 17th century. Mersenne wrote, when discussing the characteristics of equal temperament, that musicians called the lute the charlatan of instruments ‘because it passes off as good [il fait passer pour bon] that which, on good instruments, is bad’. The legerdemain in question, however, may often have been of the kind referred to by Bermudo and Aaron: a matter of left-hand artfulness to draw chords more resonant than those of equal temperament from instruments fretted in equal semitones. Every modern viol consort of any degree of finesse does this, and Marin Marais (1689) implied the use of such a technique on the solo viol when he said that his compositions in F minor would, to their detriment, sound less ‘piercing’ (‘perçant’) if the viol were tuned up a semitone (taking its F from the harpsichord’s G) for the benefit of an accompanist unfamiliar with that key. In all probability equal temperament was, then as now, a theoretical norm from which players departed flexibly for acoustical reasons – much as Renaissance keyboard musicians, confronted with instruments of rigid intonation, departed from the theoretical norm of just intonation for reasons of practicability.

Two potential sources of systematic data on the spacing of frets in old instruments are the surviving, unaltered specimens of the cittern and the like, in which the frets were usually inlaid as they are on a modern guitar; and depictions in works of art where the artist can be shown to have treated such

minutiae with sufficient care to give the rendition documentary value.

Temperaments

10. Difficulties in interpreting theoretical writings.

A casual reading of Renaissance and Baroque treatises will yield misleading clues as to contemporary practices. The prestige of the traditional, neo-Pythagorean concept of music as ‘sounding number’ led quite a few writers who were not musicians – for instance, mathematicians like Henricus Grammateus (1518), Stevin (c1600), Caramuel (1667–70), Wallis (1698) and Euler (1739) – to describe theoretical schemes that one should beware of taking as a mirror of contemporary musical norms. Other, more musicianly writers, who may have been alert to very fine nuances of current tuning, were ill-equipped mathematically to describe them in a quantitatively coherent and accurate way.

Some 15th- and 16th-century music theorists regarded ‘the comma’ as an indivisible quantity, and Gaffurius in 1518 attributed to the syntonic comma a ‘remarkable power to wander about’, adding itself to and subtracting itself from the various intervals of the scale. (This is feasible if a computer is interposed between a keyboard and some tone-generators, but one can hardly credit Gaffurius with predicting that possibility.) Several 16th-century theorists, including Aaron (1545) and Bermudo (1555) as well as Gaffurius, confused the non-identity of enharmonic ‘twins’ (such as D and E) in Pythagorean intonation, where the sharp is theoretically higher than the flat, with their non-identity in a mean-tone temperament, where the flat is higher than the sharp.

Because of the logarithmic relation between musical intervals and the corresponding string-length distances on a monochord, theorists who wrote about tempered tuning before the development of logarithms in the 1620s may be regarded, with hindsight, as having been mathematically handicapped. When Artusi in 1603 criticized Monteverdi’s theory of tempered intonation in madrigals, he said that in any case the science of music could not embrace irrational ratios. (But in fact such ratios are proper to monochord schemes for tempered scales.) Some later theorists who were just as naive as Artusi in this regard were Thomas Salmon (1705), who would divide the 5:4 major 3rd into 20:19:18:17:16 semitones, and Kirnberger (1776–9), who designed his musically very crude temperaments exclusively in terms of integer ratios, dividing the 81:80 comma into two parts as 162:161:160 and going on from there. Bédos de Celles was more charmingly naive when he said (1770, p.430) that the octave is divided into 58 commas of four different sizes, which, however, he would not specify, because ‘that is useless to our purpose’.

Even the 18th-century theorists who dealt in detail with subtle nuances in a 'good' style of unequal temperament often failed in their calculations to distinguish between the syntonic and Pythagorean commas. Vallotti in his theoretical scheme (see Well-tempered clavier, fig 1b) proposed to temper the six 5ths among the diatonic notes, F–C–G–D–A–E–B, smaller than pure by 1/6-comma and make the other six pure. This obviously refers to the Pythagorean comma (the wrinkle in the circle of 5ths; see table 1); but also said that the diatonic major 3rds would thereby be made larger than pure by 1/3-comma, which would be true only if his 1/6 and 1/3 were taken as fractions of the syntonic comma (the amount by which two pure 5ths minus two pure 4ths exceeds a pure major 3rd). Werckmeister, Neidhardt and Sorge (in his earlier writings) also used this approximative kind of reckoning.

Modern scholars have often sown worse confusions. Because Bermudo (1555, ff.103–9) discussed not only Pythagorean intonation but also an approximation to equal temperament, it has been inferred (Ward, 1953, p.33) that in equal temperament 'the mi frets were a comma higher than the fa frets'. Several early theorists have been misinterpreted as having advocated equal temperament, among them Werckmeister (mainly because he designed temperaments with no wolf 5th), Salmon (because of his 20:19:18:17:16 semitones), Lanfranco (because he said to temper the major 3rds larger than pure), Grammateus (because he would divide each of the five 9:8 whole tones of the traditional diatonic monochord into two equal parts, thereby leaving sour 5ths at B–F and B–F and Ramis de Pareia (because his ideas were new, his name occurs in the title of Barbour's doctoral dissertation, and Barbour favoured equal temperament). According to one scholar (Fose, 1992), Ramis's placing of the wolf 5th was radically mistaken and all his other advice as to which intervals must be avoided in practice was based merely on 'notational spellings' unrelated to their sound. In reality his choice of notational spellings was due to his having observed that certain intervals which looked promising on the keyboard sounded sour. Since there was, for example, a euphonious major 3rd above A but a sour one below F, he called A–C good and C–F bad. Another scholar has argued that non-keyboard musicians are 'beyond temperament' and hence 1/6-comma mean-tone temperament was the norm in 18th-century music (Haynes, 1991). There is also Kellner's alleged discovery (patented in 1975) of Bach's 'secret' tuning from clues in the design of his seal and in elaborate anagrams; he argues that since Bach was a musician, the fact that the seal has seven points and five dashes conveys a musical message, and the message is not that the keyboard has seven diatonic and five chromatic keys in each octave, but that there are seven untempered and five tempered 5ths (even though Marpurg said in 1756 (p.5) that 'the best of the unequal temperaments in use' had seven tempered ones).

One should not arbitrarily infer a rigid scheme from an altogether non-mathematical description in an old treatise. Schlick’s account of organ tuning has been subjected to an exact reduction (Lindley, 1974), and the same thing has been done to Rameau and other 18th-century theorists (Asselin, 1984). An over-exact interpretation should not be imposed upon a rough rule of thumb. Sorge said (1748, pp.32f) that Gottfried Silbermann tempered the 5ths twice as much as in equal temperament and Praetorius three times as much. But since Praetorius had clearly meant 1/4-comma mean-tone temperament (in which the 5ths are tempered 21/4 as much as in equal temperament), it is imprudence to assign, on the basis of Sorge’s remark, an exact fraction of this or that comma to ‘Silbermann’s temperament’. Sorge was only saying that it was a regular mean-tone temperament intermediate in quality between 1/4-comma mean-tone and equal temperament.

One has always to distinguish between speculative calculations, innovative proposals and descriptive references to current practice. It is instructive to compare Werckmeister’s novel monochord schemes with his non-mathematical account (1698) of good keyboard tuning; when he said that an organ could be reset to his temperament by adjusting only some of the pipes, he was clearly referring to his best-known scheme (see Well-tempered clavier, fig.1c), which Huygens, Sorge and Marpurg also tell us was the one he advocated, and allotting to a lesser practical status his own mathematical schemes involving 5ths tempered by the unhealthy amount of 1/3 comma or based on mystical virtue in the number 7. Neidhardt’s method of presentation was to describe a long series of speculative possibilities and then specify three or four as being of practical value (musicians close to J.S. Bach praised Neidhardt as a theorist of tempered tuning without ever referring to any one of his schemes in particular). Marpurg, championing equal temperament and irritated by the inept schemes of Kirnberger (‘which some [people] praised so much but nobody used’) and von Wiese, printed in 1790 a number of new schemes of unequal temperament, none of which favoured the diatonic 3rds and none of which he intended for use.

These difficulties are aggravated by the fact that, perhaps because fine shades of tuning are subtle and yet sometimes aesthetically telling, writers on the subject have often been involved in quarrels emitting more heat than light. Some well-known examples are associated, one way or another, with Ramis, Vicentino, Doni, Rameau and Kirnberger – who went so far as to say (1781, p.3) that in a ‘good’ temperament, not a single piece by J.S. Bach, C.P.E. Bach, Handel ‘and other composers’ could be transposed to any other key without making it ‘unpracticable’.

A sensible but very time-consuming way to overcome the most significant

difficulties is to combine a careful study of the treatises with musical probings using historically suitable repertory. The revised neo-Baroque temperaments of the 1990s (see Well-tempered clavier, table 1) were arrived at in this way.

Temperaments

11. Temperament and harmony.

From time to time there have been disagreements as to where the limit between ‘heavily tempered’ and ‘sour’ may lie for this or that interval. Such discussions show that a tempered interval is not the same as an out-of-tune one. Even stronger proof is the fact that tempering the chromatic scale somehow or other has for more than 500 years been a fundamental, albeit distinctive (until the 20th century) premiss of Western harmony. Using terms like ‘5th’ and ‘3rd’ for relations between pitch-classes rather than between specific pitches (thus taking ‘5th’, for instance, to mean the relation of any G to any C, of any D to any G etc.), one can say that a basic purpose of tempering is to obtain, physically and therefore conceptually, one or both of the following two kinds of equation, which would otherwise, in the raw world of untempered keyboard scales before the advent of the computer (see Just intonation, §2), be unobtainable: (1) a chain of 5ths acceptably in tune = a consonant 3rd acceptably in tune; (2) a chain of consonant major 3rds or minor 3rds acceptably in tune = a pure unison.

The mean-tone temperaments satisfy the first but not the second type of equation. A chain of three or four 5ths (such as C–G–D–A or C–G–D–A–E) makes a good consonant 3rd, but then three major 3rds (such as A–C–E–G) do not make a unison, nor do four minor 3rds (although they would if three major ones did, since the minor 3rd in a triad is the difference between a 5th and a major 3rd). One consequence of this is that mean-tone temperament is inimical to double entendre between a sharp and a flat. There is no sense of identity between, for instance, the E and the D in ex.17; instead, they are distantly related pitch classes which, although approaching each other in pitch more closely than by a semitone, cannot together take a pivotal role in intertwining of keys – as they do in ex.18, which is by a lute composer and was conceived in terms of equal temperament.

As equal temperament gradually came into widespread use on keyboard instruments during the late 18th century and the 19th, enharmonic modulations (such as in ex.18) gradually became less ‘experimental’ and then finally, in the music of composers like Wagner and Franck, perfectly routine. Nuanced well-tempered tuning was not inimical to such modulations and they can be found occasionally in the keyboard music of composers like Haydn (e.g. in the Fantasia, hXVII:4, bar 303) and even Rameau (in his L’Enharmonique, composed a few years before he endorsed equal

temperament), yet the nuances did to some extent direct the composer’s attention away from the possibilities of enharmonic modulation. This was one cause of the profound difference between Schubert’s uncanny sensitivity to all sorts of non-enharmonic relations between keys and Liszt’s apparently daring but, to a modern ear, relatively insipid exploitation, in equal temperament, of ambiguous diminished 7th chords (e.g. in the opening section of his Prometheus).

Schubert was, on the other hand, more at home in formerly ‘remote’ keys like D major than has been composers like Bach whose musical formation went back to the days of mean-tone temperament when, because there was no circle of 5ths, notes such as D, G, A and E were regarded as inherently remote. Their mitigated remoteness in the ‘good’ unequal temperaments was due to the fact that not all the imperfect consonances were equally euphonious in those tunings. A composer sensitive to the nuances would therefore tend to use the various leading-notes and triads in various more or less subtly different ways. A proper understanding of late-Baroque and Classical tonal structures must take this into account.

Without such nuances, mean-tone temperament had provided the basis for the high-Renaissance and Baroque transformation of the medieval ‘church modes’, which had originally been monophonic, into vehicles of triadic harmony (see §5 above). Some curious byways in an early 15th-century phase in the development of triadic harmony are due, however, to the fact that in a quasi-Pythagorean temperament, a chain of three or four acceptably tuned 5ths does not yield a 3rd tuned acceptably for a stable triad such as the D- and A-major chords in ex.1 and ex.2. Some apparent musical consequences of this can be observed in one of Du Fay’s earliest songs, Belle, plaissant et graciese, where the first three phrases, comprising the first of the two main sections of the piece, cadence on open 5th sonorities based on F, C and A respectively, and in the second section the main voice-part, the tenor, returns from A to F through a series of rising 4ths and falling 5ths (A–D–G–C–F) and then emphasizes again A as well as C (see ex.19), and yet no F major triad ever occurs as a vertical sonority, nor a C triad as a stable sonority (presumably because on a keyboard instrument familiar to Du Fay, the 5ths F–C–G–D–A–E were untempered and so the 3rds F–A–C–E–G were impure by an entire comma). Du Fay’s somewhat later music, however, routinely includes stable triads on F and on C (as well as on G, B etc.); he evidently participated in a 15th-century probing (see ex.1) and subsequent abandonment of quasi-Pythagorean temperament. At stake was not how keys might be intertwined as in 18th- and 19th-century modulations, but how triads might be used within one key.